Anatomy and Physiology of Animals/Cardiovascular System/Blood

Objectives

After completing this section, you should know:

- the main functions of blood
- what the term haematocrit or packed cell volume (PCV) means
- what is in blood
- what plasma is and what is in it
- the appearance and function of red blood cells (RBCs)
- the appearance and function of white blood cells particularly granulocytes, lymphocytes and monocytes
- the function of platelets and fibrinogen in blood clotting
- how oxygen and carbon dioxide are transported in the blood
- the names of some anticoagulants and their function in the body and in the vet clinic

Blood

Blood is a unique fluid containing cells that is pumped by the heart around the body of animals in a system of pipes known as the **circulatory system**. It carries oxygen and nutrients to the cells of the body and removes waste products like carbon dioxide from them. Blood is also important for keeping conditions in the body constant, in other words for maintaining **homeostasis**. It helps keep the acidity or pH stable and helps maintain a constant temperature in the body. Blood also has an important role in defending the body against disease (an important role in immunity).

A simple way to find out what is in blood is to remove a small amount from an animal and place it in a tube with a substance that prevents it from clotting (an **anticoagulant**). If you leave the tube to stand for a few hours you will find that it settles out into two layers. The top layer consists of a light yellow fluid, the **plasma**, and the bottom layer consists of **red blood cells** (RBCs). If you look very carefully you can also see a thin beige-coloured layer in between these two layers. This consists of the **white blood cells** (WBCs) (see diagram 8.1).

The above procedure is usually done more rapidly by placing the blood sample in a centrifuge for a few minutes. This machine acts like a super spin drier rotating about 10,000 times a minute and packing the heavier particles (red blood cells) at the bottom of the tube. The sample that results is called the **packed cell volume (P.C.V.**) or haematocrit. It is a very useful measurement of the concentration of red blood cells in the blood. For most animals the packed cell volume is in the range 30-45%. If it is lower than this

it means that the concentration of red blood cells is low and the animal is **anaemic**. If the reading is above this range it may mean the animal is **dehydrated.** Animals that live at high altitudes also have high P.C.V.s to compensate for the low oxygen concentration there.

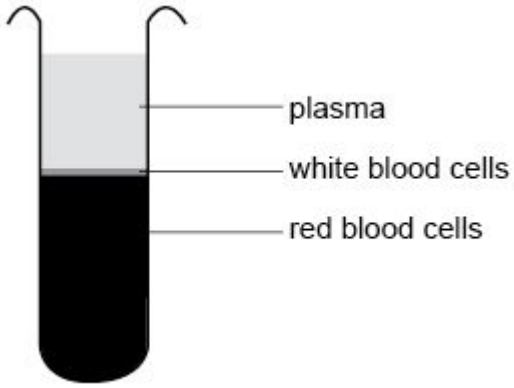

Diagram 8.1 - Packed cell volume of blood

Plasma

Plasma consists of water (91%) in which many substances are dissolved. These dissolved substances include:

- salts (or electrolytes)
- proteins
- nutrients
- waste products
- dissolved gases (mainly carbon dioxide)
- and other chemicals like hormones

Salts in Plasma

Salts in the plasma are in the form of **ions** or **electrolytes** which include sodium, potassium, calcium, chloride, phosphate and bicarbonate. Plasma transports these ions to where they are needed e.g. calcium required by the bones, they also help keep the osmotic pressure and acid-base balance (pH) of the blood within the required levels.

Blood Proteins

The proteins in the blood plasma are large molecules with important functions. Some contribute to the **osmotic pressure** (see chapter 3) and the viscosity (thickness) of the blood, and so help keep the blood volume and pressure stable. Others act as **antibodies** that attack bacteria and viruses, and yet others are important in blood **clotting**. Nutrients that are absorbed from the gut and transported to the cells in the plasma include amino acids, glucose, fatty acids and vitamins. Waste products include urea from the breakdown of proteins.

Red Blood Cells

Red blood cells are also known as RBCs or **erythrocytes**. They are what make blood red. When you look at a blood smear through a microscope, as you will in one of the practical classes, you will see that RBCs are by far the most common cells in the blood. (In fact there are about 5 million per millilitre). If you focus on an individual RBC you will see that they are shaped like discs or doughnuts with a thin central portion surrounded by a fatter margin. This shape has all sorts of advantages, one being that enables the cells to fold up and pass along the narrowest blood capillaries (See diagram 8.2).

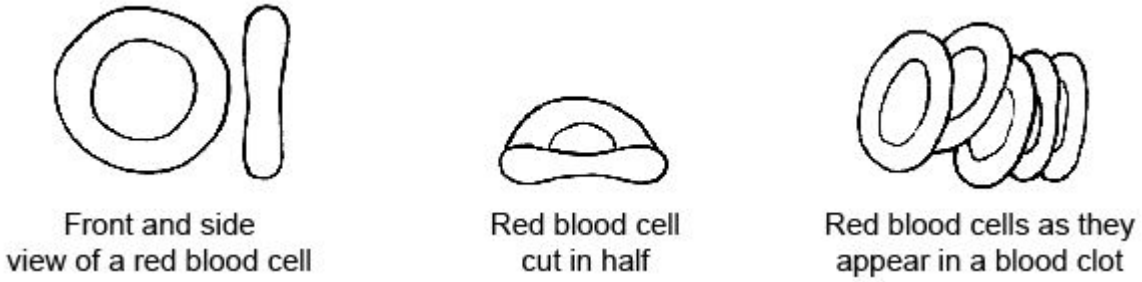

Diagram 8.2 - Red blood cells or erythrocytes

The mature RBCs of mammals have neither nucleus nor other organelles and can be thought of as sacks of **haemoglobin**. Haemoglobin is a red coloured protein containing iron, which joins with oxygen so the blood can transport it to body cells. RBCs are made continuously in the bone marrow and live about 120 days. They are then destroyed in the liver and spleen and the molecules they are made from recycled to make new RBCs. Anaemia results if the rate at which RBCs are **destroyed** exceeds the rate at which RBC'c are 'produced'.

Note that if you happen to look at bird's, reptiles, frogs or fishes blood down the microscope you will see that these vertebrates all have RBCs with a central nucleus.

White Blood Cells

White blood cells or **leukocytes** are far less numerous than red blood cells. In fact there is only about one white cell for every 1000 red blood cells. Rather than being white, they are actually colourless as they contain no hemoglobin although unlike RBCs they do have a nucleus. If you make a blood smear and look at it under the microscope it is difficult to see the white blood cells at all. To make them visible you need to stain them with special dyes or stains. There are a variety of stains that can be used, but most dye the nucleus a dark purple or pink colour. The stains may also show up the granules present in the cytoplasm of some white blood cells. White blood cells are divided into two major groups depending on the shape of the nucleus and whether or not there are granules in the cytoplasm.

1. **Granulocytes** or **polymorphonuclear leucocytes** ("polymorphs" or "polys") have granules in the cytoplasm and a purple lobed nucleus (see diagram 8.3). The most common (**neutrophils**) can squeeze out of capillaries and are involved in engulfing and destroying foreign invaders like bacteria (see diagram 8.4). Some (**eosinophils**) combat allergies and increase in numbers during parasitic worm infections. Others (**basophils**) produce **heparin** that prevents the blood from clotting.

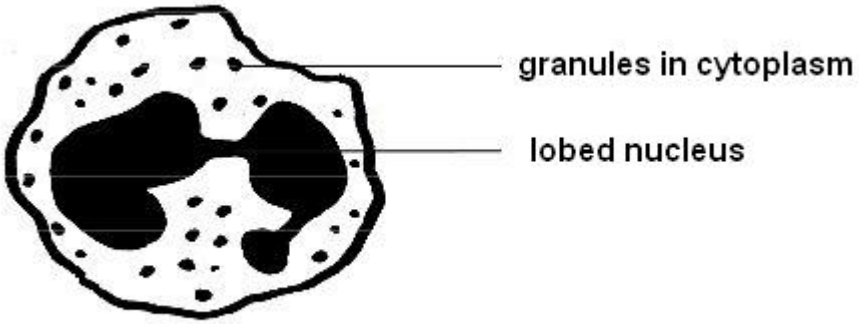

Diagram 8.3 - A granulocyte

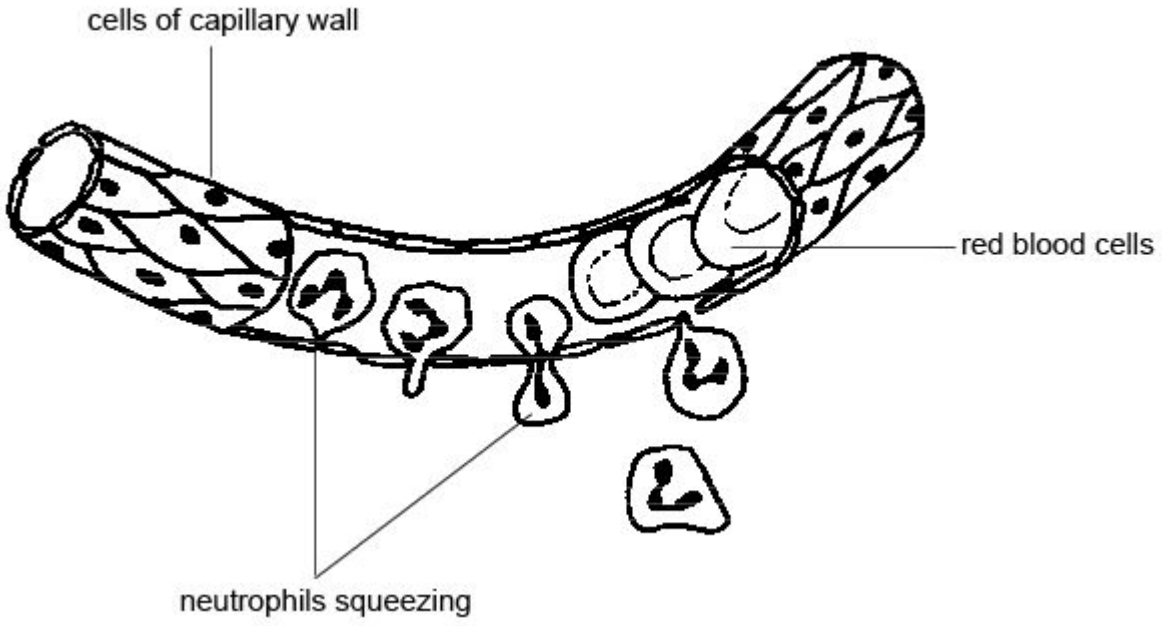

Diagram 8.4 - Neutrophils escaping from a capillary

2. **Agranulocytes** or **monomorphonuclear leucocytes** have a large unlobed nucleus and no granules in the cytoplasm. There are two types of agranulocytes. The most numerous are **lymphocytes** that are concerned with immune responses. The second type is the **monocyte** that is the largest blood cell and is involved in engulfing bacteria etc. by phagocytosis (see diagram 8.5).

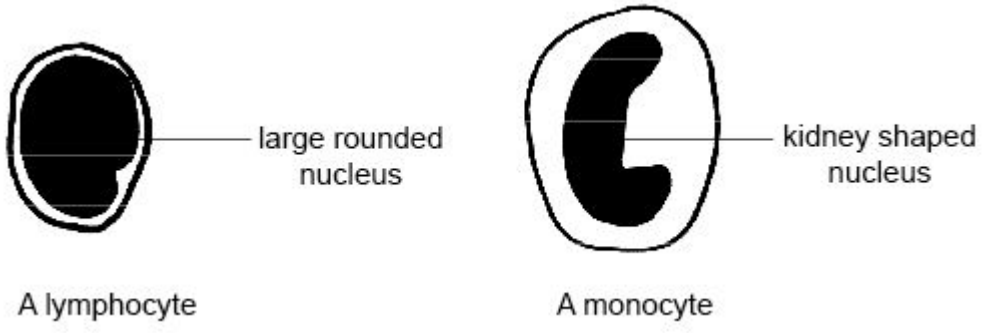

Diagram 8.5 - Agranular leucocytes

Platelets

As well as red and white blood cells, the blood also contains small irregular shaped fragments of cells known as platelets. They are involved in the clotting of the blood (see later).

Transport Of Oxygen

The purpose of the haemoglobin in red blood cells is to carry oxygen from the lungs to the tissues. In fact it allows the blood to carry about 25 times more oxygen than it would be able to without any haemoglobin.

When oxygen concentrations are high, as in the blood capillaries in the lungs, haemoglobin combines with oxygen to form a compound called **oxyhaemoglobin**. This compound is bright red and makes the **oxygenated blood** that spurts from a damaged artery its characteristic bright red colour. When the blood reaches the tissues where the oxygen concentrations are low, the oxygen separates from the haemoglobin and diffuses into the tissues. The haemoglobin in most veins has given up its oxygen and the blood is called **deoxygenated blood**. It is a purple-red colour.

Carbon Monoxide Poisoning

Carbon monoxide is a colourless, odourless gas found in car exhaust fumes and tobacco smoke. It combines with haemoglobin just like oxygen but does not let go. This means the haemoglobin molecules are not available to carry oxygen to the tissues and the animal or human suffocates. Carbon monoxide poisoning is often fatal but can be treated by giving the patient pure oxygen that slowly replaces the carbon monoxide. This could be conceived numerically as a probability issue: carbon monoxide binds 200 times stronger than oxygen to the iron atom in haemaglobin , but this bond I has dynamic states where the CO molecule moves away temporarily from the iron atom and then it depends on chances of an oxygen atom being near enough to the iron atom to takeover the electrostatic bond . if there are enough oxygen molecules around, the carbon monoxide molecule is crowded out and moved further away from the iron atom , enough to overcome the 200 times attractivity of carbon monoxide to the iron moiety.

Transport Of Carbon Dioxide

Carbon dioxide is a waste gas produced by cells. It diffuses into the blood capillaries where it is carried to the lungs in the blood. Most is carried in the plasma as **bicarbonate ions** but a small amount is dissolved directly in the plasma and some combines with haemoglobin.

Transport Of Other Substances

The blood carries water to the cells and organs as well as soluble food substances (sugars, amino acids, fatty acids and vitamins) and hormones dissolved in the plasma. These are delivered to the cells via the **tissue fluid** (see later in this chapter) that surrounds them. Blood also picks up the waste products like

carbon dioxide and urea from the cells and is important in distributing the heat produced in the liver and muscles all over the body.

Blood Clotting

The mechanism that causes the blood to clot is easily seen when you or your animals are injured. However, minor injuries occur all the time in areas that experience wear and tear like the intestine, the lungs and the skin. Without the clotting mechanism, animals would quickly bleed to death from minor injury and internal **haemorrhage.** This is what happens in animals and people with clotting disorders like haemophilia, as well as animals that are poisoned with rat poisons like warfarin.

Platelets are important in blood clotting. When blood vessels are damaged, substances released cause the blood platelets to disintegrate. This stimulates a complex chain of reactions, which causes the protein **fibrinogen** to be converted to **fibrin**. Fibrin forms a dense fibrous network over the wound preventing the escape of further blood. **Calcium** and **vitamin K** are essential for the clotting process and any deficiency of these may also lead to clotting problems.

Serum And Plasma

When blood clots it separates into the clot that contains most of the cells and platelets leaving behind a straw coloured fluid. This fluid is called **serum**. It looks just like plasma and is similar in composition except for one big difference. It doesn't contain fibrinogen, the protein that forms the clot.

Anticoagulants

Anticoagulants are substances that interfere with the clotting process. When blood is collected for transfusion or testing it is often important to prevent it clotting and there are a number of different anticoagulants you can use for this. Tubes containing the different anticoagulants are coded with different colours for easy recognition.

1. **Heparin** (colour code - green) is a natural anticoagulant produced by the white blood cells but it is also used routinely in the laboratory with samples to be tested for heavy metals like lead.
2. **EDTA** (colour code – lavender) is used for routine blood counts.
3. **Fluoroxylate** (colour code – grey) is used for biochemical tests for glucose.
4. **Citrate** (colour code – light blue) is used for the storage of large quantities of blood, such as used in transfusions.

Haemolysis

Haemolysis is the breakdown of the plasma membrane of red blood cells to release the haemoglobin. We have already met this process when discussing osmosis, for haemolysis often occurs when red blood cells are placed in a hypotonic solution and water flows in through the semi permeable plasma membrane to

swell and eventually burst the cell. It is therefore important when collecting blood from an animal to make sure there is no water in the syringe or tube. Too much movement due to shaking the tube or sucking up the blood too vigorously can also break down the plasma membrane and cause haemolysis.

Blood Groups

If you have given blood recently you may know your blood group. It may be blood group O, A or B or even AB, the rarest group. Blood groups are the result of different molecules called antigens on the outside of red blood cells. These cause antibodies to be formed that attack viruses and bacteria. Knowledge of a person's blood group is important when giving transfusions because if blood of another incompatible blood group is given to a patient the red blood cells stick together and block the blood vessels and may lead to death.

Blood groups also exist in many animals. There are three blood groups in cats and great care has to be taken that the groups are compatible when transfusing exotic breeds. The situation is slightly different in dogs. They have a number of blood groups but there is usually no problem with the first blood transfusion a dog receives. However, this first transfusion sensitises the immune system so that a problem may arise with the second and subsequent transfusions.

Haemolysis can occur in the living animal when it is exposed to various poisons and toxins. This may happen when, for example, it eats a poisonous plant, is bitten by a snake or infected with bacteria that destroy red blood cells (haemolytic bacteria).

Blood Volume

Blood accounts for between 6-10% of the body weight of animals, varying with the species and the stage of life. Animals can not tolerate losses of greater than 3% of the total volume when the condition known as **shock** occurs.

Summary | Blood

- The main functions of blood are transport of oxygen, food, waste products etc., the maintenance of homeostasis and defending the body from disease.
- Blood consists of fluid, plasma, in which red and white blood cells are suspended. The blood cells typically make up 30-45% of the blood volume.
- Plasma consists of water containing dissolved substances like proteins, nutrients and carbon dioxide.
- Red Blood Cells contain **haemoglobin** to transport **oxygen**.
- **White Blood Cells** defend the body from invasion. There are 2 kinds:
- **Granular white cells** include **neutrophils, basophils** and **eosinophils**. Neutrophils which destroy bacteria are the most numerous. Eosinophils are involved with allergies and parasitic infections.
- **Non-granular white cells** include **lymphocytes** that produce antibodies to attack bacteria and viruses and **monocytes** that engulf and destroy bacteria and viruses.
- **Platelets** are involved in blood clotting.

Worksheet

The exercises in the Blood Worksheet (http://www.wikieducator.org/Blood_Worksheet) will help you learn how to identify the different types of blood cell and what their functions are.

Test Yourself

1. The liquid part of blood is known as:

2. There are two main types of cells in blood. They are:

    a)
    b)

3. The most numerous cells in blood are:

4. The main function of the red blood cells is:

5. How would you tell a white cell from a red cell when looking at them through a microscope? (Give at least 2 differences)

6. How does the blood help fight invasion by bacteria and viruses?

7. What would happen to blood if there were no platelets?

Test Yourself Answers

Websites

- http://www.getbodysmart.com/ap/circulatory/heart/menu/heart.html Get Body Smart

Shows constituents of blood including RBCs, white cells, platelets and plasma. Even shows how to make a blood smear and identify the white cells on it as well as make and read a haematocrit. Some parts are a little too advanced.

- Wikipedia has good information of red and white blood cells.
    - http://en.wikipedia.org/wiki/Red_blood_cell Red blood cells
    - http://en.wikipedia.org/wiki/White_blood_cell White blood cells

Glossary

- Link to Glossary (https://en.wikibooks.org/wiki/Anatomy_and_Physiology_of_Animals/Glossary)